Damping Measurement of Advanced Composite Materials for Turbomachinery Applications

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A widely held assumption is that fiber-reinforced composite materials possess more inherent material damping than metals or monolithic composites. With this in mind, the objective of this study is to quantify the material damping of fiber-reinforced composite materials that can be used in turbomachinery applications. Fiber-reinforced ceramic-matrix composite materials possess high-strength, low-weight, and high-temperature capabilities—qualities that turbine end-component materials must have. The additional quality of higher damping will allow components to be less complex and able to withstand higher dynamic loading.

This particular damping study was approved in October of 1993 and is scheduled for completion in January of 1996. The idea to study the damping capacity of composite materials came from the realization that, while there is an interest in developing ceramic integrally bladed disk (blisk) components, damping data were not readily available.

The objective of the task is to measure the inherent material damping capacity of composite materials which have promise for use in rocket engine blisk applications. Such damping information is required for dynamic analysis that can predict the dynamic stress of a component under loading.

Samples of various advanced composite materials were selected for testing. Damping tests were performed on beam samples (20.32 centimeters long by 2.54 centimeters wide by 0.3175 centimeter thick) for several modes of vibration in a free-free boundary condition. These materials represented various types of composite materials: fiber-reinforced ceramic-matrix composites, carbon/carbon composites, monolithic silicon nitride, and Inconel 718. Inconel 718, a nickel-based superalloy currently used in rocket engine turbopump applications, served as the baseline material. Test data revealed that the fiber-reinforced composites provided more material damping than the baseline material—in some cases as much as one-third more damping (see fig. 78).

Two fiber-reinforced ceramic-matrix composite disks (22.86 centimeters in diameter) have been purchased from Oak Ridge National Laboratory for damping tests. These disks are representative of rocket engine turbines, bladed disks, and blisks in size and basic geometry. Two different fiber architectures are represented: polar and quasi-isotropic cloth layup. The strength of the component is dependent on the fiber type and architecture; polar architecture can provide good strength for turbine applications but is difficult to produce, while the cloth layup is easy to produce but not quite as strong.

The majority of the tests have been performed at MSFC, while additional temperature and vacuum tests have been performed at the Lewis Research Center. Damping tests in vacuum provide the best results because the damping caused by air resistance has been eliminated. Test data are stored in a data base developed using the commercially available materials data base software M/Vision.

Test data can aid in the selection of materials for turbomachinery applications. Turbopump components produced from composite materials will allow the engine to be lighter, thus providing an improved thrust-to-weight ratio. Composites in the turbine area could allow the engine to run at higher temperatures, thereby increasing performance and equating to larger payloads (or the delivery of smaller payloads to higher orbits).

With the commercialization of space, this data can be utilized by private companies in the development of space vehicles that will be lighter, be able to perform better, and do so at lower development and operations costs.

Composite materials can offer lighter weight and less costly components for rocket engine applications. Test data have shown that fiber-reinforced composites provide higher material damping than the selected baseline advanced metal alloy. Additionally, with their higher damping, composites may increase the life of components subjected to high-vibration environments.

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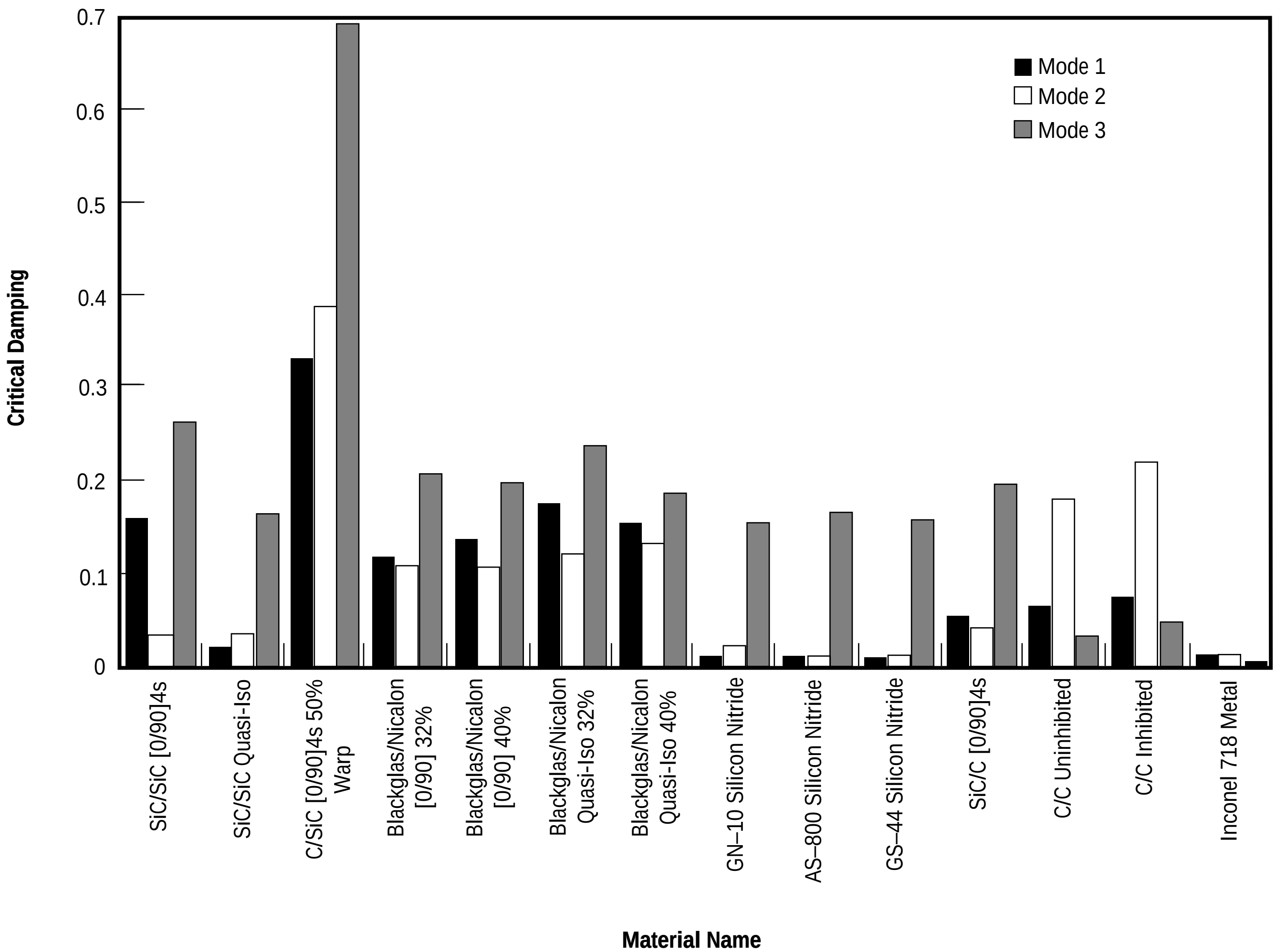

FIGURE 78.—Fiscal year 1995 damping study test results.